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Sex differences in pacing during half-marathon and marathon race

Running head: Sex difference in pacing in marathon running

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Abstract

The main aim of the present study was to examine differences in pacing between half-marathon and marathon in men and women. A total of 17,525 finishers in the marathon (n=4,807 men; n=1,278 women) and half-marathon race (n=7,624 men; n= 3816 women) in Vienna 2017 were considered.Their pacing was assessedthrough five race segments (0-23.7%, 23.7-47.4%, 47.4-71.1%, 71.1-94.8% and 94.8-100%) of the race. Compared to marathon, [where absolute average change of speed (ACS) was 5.46% and 4.12% in men and women, respectively], a more even pacing was observed in half-marathon in both sexes (ACS=3.60% and 3.36% in men and women, respectively). The more even pacing in women previously observed in marathon races was verified in half-marathon, too. However, the sex difference in pacing was smaller in half-marathon than in marathon. Since men and women endurance runners participate inboth races,sport practitioners would have great benefit from these results, since they could establish sex based personalized race strategies and training programs.

Keywords: aerobic capacity; endurance; gender; performance; running

Introduction

Pacing can be defined as moment-to-moment distribution ofpower output, speed or energetic reserves during a particularsports event (Abbiss & Laursen, 2008; Roelands, de Koning, Foster, Hettinga, &Meeusen, 2013). Along with training and proper diet, optimal pacing is a crucial aspect of successful finish in long distance events, such as half-marathon, marathon or running split of triathlon (Angus, 2014; Knechtle, Käch, Rosemann, & Nikolaidis, 2019). Pacing in long distance runningproves to be an important factorin both achieving record braking results in elite runners as well as optimizing individual performance in recreational runners (Angus, 2014; Santos-Lozano, Collado, Foster, Lucia, &Garatachea, 2014).Moreover, optimal pacing is crucial inpreventing unreasonably homeostatic disturbances during the racein addition to decreasing the risk of musculoskeletal injuries (De Koning et al., 2011).

Numerous studies have been examining pacing in long distance running, primarily in ultra-marathon (Lambert, Dugas, Kirkman, Mokone &Waldeck, 2004;R.Hoffman, 2014) and marathon (Deaner, Carter, Joyner, & Hunter, 2015; Knechtle et al., 2016; Nikolaidis, Rosemann & Knechtle, 2018).Several studies showed“positive pacing” profiles in these events,with significant decrease in speed after approximately 30 km in marathon event (March, Vanderburgh, Titlebaum, & Hoops, 2011; Nikolaidis & Knechtle, 2018).This can be attributed to a muscle glycogen depletion (Roepstorff et al., 2002), also known as “hitting the wall”, neuromuscular fatigue (Millet, 2011) or even blood lactate accumulation, due to a fast start of the race (Young, 2007), caused by a “risky” start (Deaner et al., 2015). However, only few studies have ever examined pacing in half-marathon. Half-marathon events are becoming as attractive as marathon events, withits popularity constantly increasing among the running community (Hanley, 2016; Knechtle et al., 2016). Theyprove to be easier to complete,with less time needed for preparation, comparing to marathon. Information on pacing profiles for half-marathon runners would be helpful in designing appropriate training programs, as well asracing strategies in comparison to marathon.

The most recent studies (Nikolaidis, Cuk & Knechtle, 2019) examined pacing in half-marathon, in only one event, in a single year, while Hanley (2016) assessed pacing in merely elite runners. Finally, Knechtle and Nikolaidis (2018) assessed pacing in half-marathon without comparing it to the marathon pacing profiles. Considering that, pacing in half-marathon, as well as comparison between marathon and half-marathon pacing profiles should require further assessment.

Previous research showed that women had more stable pacing in long distance running than men (March et al., 2011; Deaner et al., 2015; Nikolaidis et al., 2018). The sex difference in pacing could beattributed to several physiological factors, such as lesser fatigability of women's skeletal muscle(Hunter, 2014) or men's greater vulnerability to muscle glycogen depletion (Roepstorff et al., 2002).Aforementioned sex differences could also have psychological background. Namely, men often have a tendency towards fast start of the race(Deaner et al., 2015), thus increasing blood lactate level or exhaust muscle glycogen levels earlier in the race, often called "hitting the wall" (Coyle, 2007; Buman, Brewer, Cornelius, Van Raalte&Petitpas, 2008). Therefore, the further assessment of pacing in men and women, regarding both marathon and half-marathon would be beneficial for sport scientists as well as coaches working with both marathon and half-marathon runners. That way, they could establish sex based personalized race strategies and training programs.

Based on the disadvantages regarding previous studies, the first aim of this study was to establish pacing profile in half-marathon event. Second aim of this study was toassess differences inpacing profilesbetween marathon and half-marathon events, as well as, toassess pacing differences in men and women, regarding both marathon and half-marathon events. Finally,establishing the pacing strategy that works best for the men and women in both marathon and half-marathon,corresponds to the third aim of this study.

Materials and Methods

Ethical approval

This study was approved by the Institutional Review Board of Kanton St. Gallen, Switzerland, with a waiver of the requirement for informed consent of the participants as the study involved the analysis of publicly available data. The study was conducted in accordance with recognized ethical standards according to the Declaration of Helsinki adopted in 1964 and revised in 2013.

Participants

For the purpose of this study, we have included official results and split times from2017 Vienna City Marathon (www.vienna-marathon.com). A totalnumber of 6,085participants ofthe 2017 Vienna marathon (n=4,807 men; n=1,278 women) and 11,440 participants of the 2017 Vienna half-marathon (n=7,624 men; n= 3816 women) were included. Participants who did not finish any of the races, or did not have recorded any of the split times were excluded from the study.Both marathon and half-marathon were held on the same day on flat, officially certified track, with elevation difference of50 m(ranging from 154 – 210m). Note that the half marathon race was entirely contained within the marathon race. During the race day, weather was cloudy, with temperature ranging from 7.8°C at 9a.m. to 11.8°C at 2p.m., without strong wind or excess humidity.

Data analysis

In the first step of data analysis, we have calculated the average race speed for each participantin half-marathon and marathon. Additionally, we have calculated average running speed in five race segments, for both marathon and half-marathon as previously reported by Nikolaidis, Cuk and Knechtle (2019). Segment 1 included average running speed from 0 to 23.7% of both races. That corresponds to 0 to 10km segment for marathon and 0 to 5 km segment for half-marathon. Furthermore, Segment 2 included average running speed from23.7 to 47.4% of both races, corresponding 10 to 20km for marathon and 5 to 10km for half marathon. Average running speed from 47.4 to 71.1% of the races (*i.e.,*Segment 3) considered segments from 20 to 30 km in marathon as well as 10 to 15km segment for half-marathon. Segment 4 included average running speed from 71.1 to 94.8% of both races. That corresponds to 30 to 40km segment for marathon and 15 to 20km segment for half-marathon. Finally, endspurt or Segment 5 considered average running speed from 94.8 to 100% of the race. In terms of race distances, that corresponds to the segment from the 40thkm, to the race finish (42.195 km) in marathon as well as from the 20thkm, to the race finish (21.0975km) in half-marathon.

Consecutively, we have calculated the individual percentage of Average change in speed for each of the five segments[ACSS = 100-(Average running race speed / Average running speed for segment x 100)].This methodology was previous utilized byNikolaidis, Cuk and Knechtle (2019) and Santos-Lozano et al. (2014). Finally, we have calculated absolute average change ofspeed (in percentage), through the five race segments [ACS = (ACSS1+ ACSS2+ ACSS3+ ACSS4+ ACSS5) / 5], for each participant.Note that use of both positive and negative values could lower the mean of the changes. To address this issue, we transformed all values to the absolute values (*i.e.* only positive values).

Statistical analysis

Prior to all statistical tests, descriptive statistics were calculated as a mean, standard deviation, minimum and maximum values. Data distribution normality was assessed by visual inspection of histograms and QQ plots. Observed data showed rather normal distribution. In addition, a mixed between-within analysis of variance (ANOVA) was performed for ACSS to test differences between segments (*i.e.,* Segments 1 to 5; within-subjects factor), race (*i.e.,* marathon and half-marathon; between-subjects factor) as well as their interaction (segment × race). To further investigate pacing differences between marathon and half-marathon, we have performed additionalmixed between-within ANOVAs for ACSS. First, two ANOVAs were performed to assess differences between segments (*i.e.,* Segments 1 to 5; within-subjects factor), race (*i.e.,*marathon and half-marathon; between-subjects factor) as well as their interaction (segment × race) separately for men and women. Another two ANOVAs were performed to assess differences between segments (*i.e.,*Segments 1 to 5; within-subjects factor), sex (*i.e.,*men and women), as well as their interaction (segment × sex) separately for marathon and half-marathon. Finally, one two way ANOVA was performed on ACS to assess differences between races (*i.e.,*marathon and half-marathon), sex (i.e., men and women) as well as their interaction (race × sex). For all ANOVAs, post-hoc Bonferroni test was performed.Effects size was presented via eta squared (η^2), where the values of.01, .06 and above .14 were considered small, medium, and large, respectively (Cohen, 1988).Alpha level was set at $p<0.05$.All statistical tests were performed using Microsoft Office Excel 2007 (Microsoft Corporation, Redmond, WA, USA) and SPSS 20 (IBM, Armonk, NY, USA).

Results

The segments speed and entire race speed of participants were presented in Table 1.Regardless of their sex, both marathon and half marathon runners showed positive pacing pattern through the first four segments, with the characteristic endspurt (**Table 1**). Moreover, largest deviation of running speed was observed in marathon men, whereas the smallest deviation of running speed was observed in half-marathon women. Further examination of pace profiles was presented in **Figures 1, 2, and 3**.

In regards to marathon and half marathon runners of both sexes (**Figure 1**), significant main effects of segment [$F(4,17520) = 8736.9$, $\eta^2 = 0.31$, $p < 0.01$], race [$F(4,17520) = 48.3$, $\eta^2 < 0.01$, $p < 0.01$] and segment × race interaction [$F(4,17520) = 837.6$, $\eta^2 = 0.03$, $p < 0.01$] were observed.On average, percentage of speed change was 2.19% greater in marathon than in half-marathon ($p < 0.01$). Moreover, in both marathon and half marathon runners, each segmentshowedsignificant differences in speed change than the other ($p < 0.01$).

Regarding only men runners (**Figure 2; panel a**), significant main effects of segment [$F(4,12421) = 6524.3$, $\eta^2 = 0.32$, $p < 0.01$], race [$F(4,12421) = 119.1$, $\eta 2 < 0.01$, $p <0.01$] and segment× race interaction[$F(4,12421) = 951.5$, $\eta^2= 0.04$, $p < 0.01$] were observed. On average, men marathon runners showed 2.49% greater speed change than men half marathon runners ($p < 0.01$).Significant main effects of segment [$F(4,5088) = 1968.7$, $\eta^2 2 = 0.27$, $p < 0.01$], race [$F(4,5088) = 172.6$, $\eta^2= 0.01$, $p <0.01$] and segment × race interaction [$F(4,5088) = 73.8$, $\eta^2= 0.01$, $p < 0.01$] were observed in women runners as well (**Figure 2; panel b**). On average, women marathon runners showed only 1.00% greater speed change than women half marathon runners ($p < 0.01$). Regarding marathon runners (×), significant main effects of segment [$F(4, 6079) = 2392.4$, $\eta^2 = 0.27$, $p < 0.01$], sex [$F(4, 6079) = 87.7$, $\eta^2 < 0.01$, $p < 0.01$] and segment

×sex interaction [$F(4, 6079) = 108.6$, $\eta^2 = 0.01$, $p < 0.01$] were observed. Specifically, for each segment, men showed greater speed change than women ($p < 0.01$), which, on average corresponds to 1.59%.

Significant main effects of segment [$F(4,11430) = 3244.4$, $\eta^2 = 0.21$, $p < 0.01$], sex [$F(4, 11430) = 18.4$, $\eta^2 < 0.01$, $p < 0.01$] and segment ×sex interaction [$F(4, 11430) = 18.7$, $\eta^2 < 0.01$, $p < 0.01$] were observed in half marathon as well (**Figure 2; panels a and b**). In contrast to our previous findings, significant difference at alpha level 0.01 between men and women was found only in segment 3 and 5 where men showed greater fluctuation of speed than women by 0.52% (on average). In segment 1 and 4, women showed trivial, 0.25%, speed change than men ($p < 0.05$), whereas in segment 2, no significant differences was observed (0.03% difference; $p = 0.57$). Finally, in men and women runners in both marathon and half marathon, each segment each segment showed significant differences inspeed change than the other ($p < 0.01$).

Regarding ACS (**Figure 3**), significant main effects of race [$F(3,17521) = 464.8$, $\eta^2 = 0.03$, $p < 0.01$], sex [$F(3,17521) = 124.9$, $\eta^2 = 0.01$, $p < 0.01$] and race× sex interaction [$F(3,17521) = 71.9$, $\eta^2 < 0.01$, $p < 0.01$] were observed.

Discussion

In this paper, we establishedthe pacing profile in a half-marathon event, as a first aim of this study. A second aim of this study was to assess differences in pacing profiles between marathon and half-marathon running. And finally, we assessed pacing differences in men and women, regarding both marathon and half-marathon running. Half-marathon runners establish a positive pacing profile, *i.e.* constantly slowing down in speed, as the race progresses, with the characteristic endspurt in the final 1.0975 meters. A similar pacing profile was established in marathoners as well, however, changes in running speed werehigher in marathoners in regards to half-marathoners. Finally, men marathon runners showed greater speed fluctuations than women, whereas in half-marathon both men and women had rather similar pacing profiles.

Half-marathon pacing

Half-marathon runners appear to have positive pacing profile (Figure 1), with the endspurt in the final segment of the race. Similar results were obtained in another half-marathon studyin elite runners (Hanley, 2016). It appears that even elite runners had positive pacing profile in half-marathon, however, larger sample of recreational runners, in our study, showed greater plunge in speed between 15^{th} and 20^{th}kilometre. Moreover, elite runners from Hanley's study (2016) showed endspurt faster than average race speed, whereas in our study, endspurt in half-marathon runners was still 2.29% slower than average race speed (Figure 1). Coaches could use these findings, for example, to advise novice runners to pay particular attention to pacing training in half-marathon. Finally, the most recent study (Nikolaidis, Cuk & Knechtle, 2019), also showed positive pacing in half-marathon, however, with no endspurt. That can be attributed to the specificity of the race; therefore, further research in this field is needed.

Half-marathon versus marathon pacing

Several studiesinvestigating pacing in marathoncomply with our findings (March et al., 2011; Deaner et al., 2015; Nikolaidis & Knechtle, 2017).However, very few studies havedirectly compared pacing in marathon and half-marathon (Nikolaidis, Cuk & Knechtle, 2019). When compared to the marathon, similar pacing profile was established in half-marathon (*i.e.* positive pacing with endspurt). However, fluctuations in speed were more even in half-marathon in regards to the marathon.First segment in marathon was more than 5% faster than the average race speed, whereas half-marathon runners were less than 2% faster.Similar to that, in the fourth segment, marathon runners showed greater loss of speed, followed by slower endspurt than half-marathon runners.The knowledge of the near finish might motivate the runners to mobilize the last reserves for end spurt (Nikolaidis & Knechtle, 2018).However, a fast start of the marathon runners can cause an additional fatigue induced in the fourth segment (Young, 2007), therefore, slowing the end spurt. Consequently, we can argue that half-marathon runners were probably less fatigued with more energy saved for the endspurt.

Sex differences in pacing

When sex differences were observed, women marathon runners showed less running variability than men in the same event, which corresponds with previous studies (March et al., 2011; Deaner et al., 2015; Nikolaidis et al., 2018).Observed sex differences have been previously attributed to differences in physiology and decision making between women and men. In particular, men may be more likely to adopt a “risky” pace, where an individual begins the race with a fast pace (relative to their ability) thus increasing likelihood of slowing later (Deaner et al., 2015). Moreover, some studies have reported that men tends to start fast, since they are more competitive than women (Ogles & Masters, 2003).However, that was not the case in half-marathon event, given that women had rather similar pacing profile comparing to men. We can assume that physiological, rather than psychological factors can influence additional slowing in marathon men (and not half-marathon men), such as, men muscle glycogen depletion (March et al., 2011), better utilization of fat by women(Tarnopolsky, 2008) or more fatigue resistant type I muscle fibres in women (Hunter, 2014). However, future research is needed to address this issue. These novel findings come with great practical application. Sport scientists and practitioners can now focus their research on how to optimize men marathon pacing,to be similar to women's or half-marathoners i.e. with less variability (or possibly to utilise negative pacing profile).

Limitations

One of the limitations of this study is the lack of additional aspects that could influence pacing, such as previous training routine, running experience or personal characteristics. Moreover, this study hasanalyzed pacing profiles in marathon and half-marathon races in only oneevent (*i.e.* "2017 Vienna City Marathon"). However, 45% of all 2017 Vienna City Marathon participants were foreign runners, and, therefore, we can exclude the factor of only one nation running this event. Nevertheless, further examination of pacing in half-marathon is needed, since pacing can vary, depends of the race profile, weather conditions or altitude.

Conclusions

In summary, the pacing in half-marathon was more even than in marathon. The more even pacing in women previously observed in marathon races was verified in half-marathon, too. However, the sex difference in pacing was smaller in half-marathon than in marathon. Since both elite and recreational men and women runners participate in marathon and half-marathon, sport practitioners would have great benefit from these results, since they could establish sex based personalized race strategies and training programs.

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Table 1. Segments and race speed for men and women, marathon and half marathon runners

		Segment 1 speed (m/s)	Segment 2 speed (m/s)	Segment 3 speed (m/s)	Segment 4 speed (m/s)	Segment 5 speed (m/s)	Average race speed (m/s)
Men 42.2km N=4807	Mean	3.210	3.152	3.116	2.856	2.880	3.059
	SD	0.450	0.453	0.483	0.526	0.490	0.462
	Min	2.028	1.916	1.716	1.521	1.565	1.931
	Max	5.522	5.420	5.429	5.495	5.474	5.466
Women 42.2km N=1278	Mean	2.923	2.854	2.836	2.663	2.731	2.807
	SD	0.362	0.373	0.397	0.418	0.390	0.376
	Min	2.082	1.986	1.749	1.549	1.421	1.939
	Max	4.808	4.866	4.978	4.819	4.545	4.841
Men 21.1km N=7624	Mean	3.152	3.137	3.118	2.972	3.025	3.100
	SD	0.449	0.437	0.457	0.495	0.496	0.453
	Min	2.010	1.814	1.698	1.605	1.488	1.808
	Max	5.149	4.878	4.946	4.990	4.951	4.968
Women 21.1km N=3816	Mean	2.857	2.838	2.809	2.680	2.752	2.803
	SD	0.322	0.327	0.351	0.376	0.378	0.338
	Min	1.980	1.857	1.599	1.464	1.412	1.760
	Max	4.878	4.744	4.730	4.562	4.425	4.706

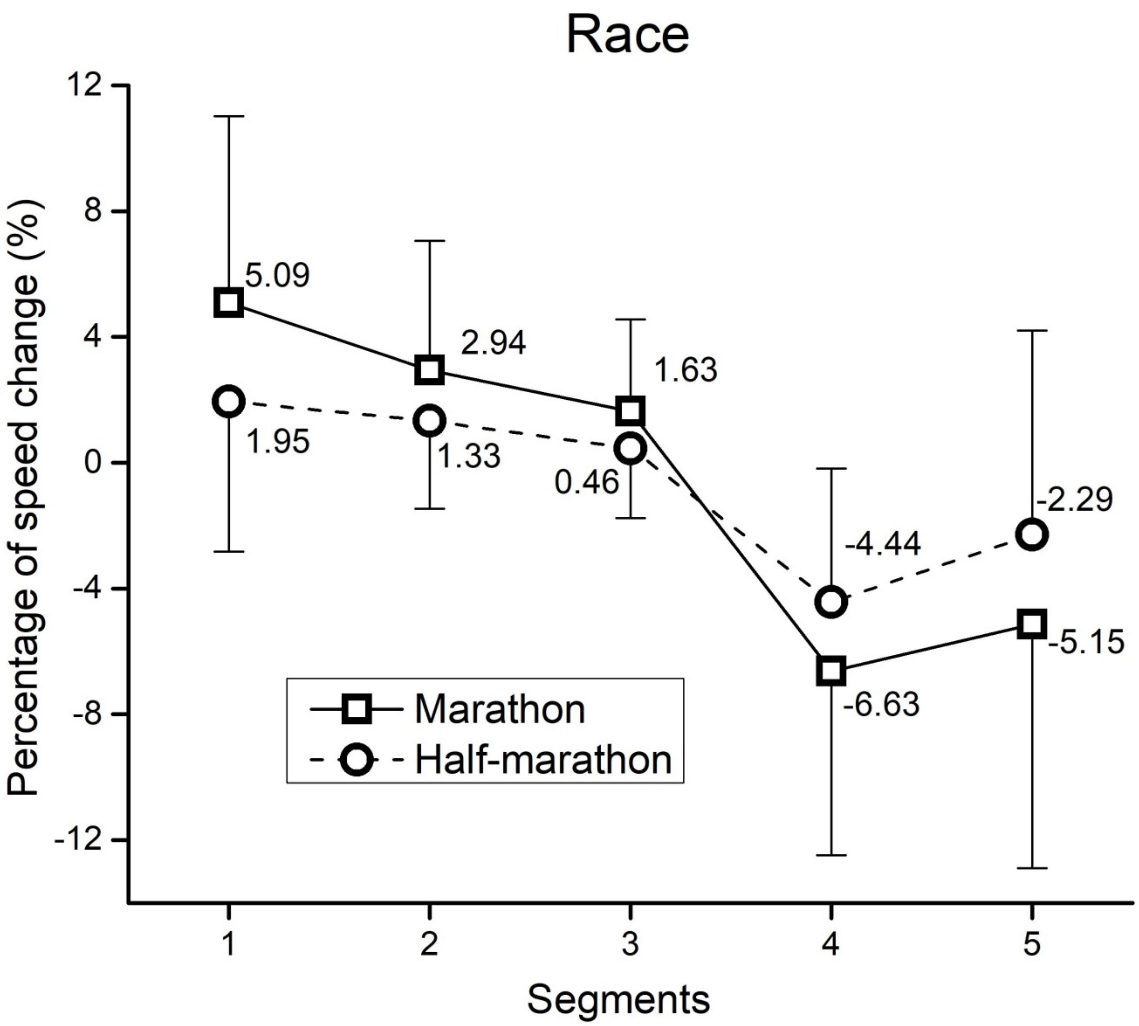
Figure captions

Figure 1. Average changes of speed in every race segment, calculated as a percent change of the mean race time in marathon and half-marathon. Error bars present standard deviation.

Figure 2. Average changes of speed in every race segment, calculated as a percent change of the mean race time in marathon and half-marathonin women and men.Error bars present standard deviation.

Figure 3. Absolute average changes of speed in marathon and half-marathon in women and men.Error bars present standard deviation.**$p<0.01$; *$p<0.05$; ##$p<0.01$.

Figure 1



Race
Percentage of speed change (%)
12
8
4
0
-4
-8
-12
5.09
2.94
1.63
1.95
1.33
0.46
-4.44
-2.29
-6.63
-5.15
Marathon
Half-marathon
1
2
3
4
5
Segments

Figure 2

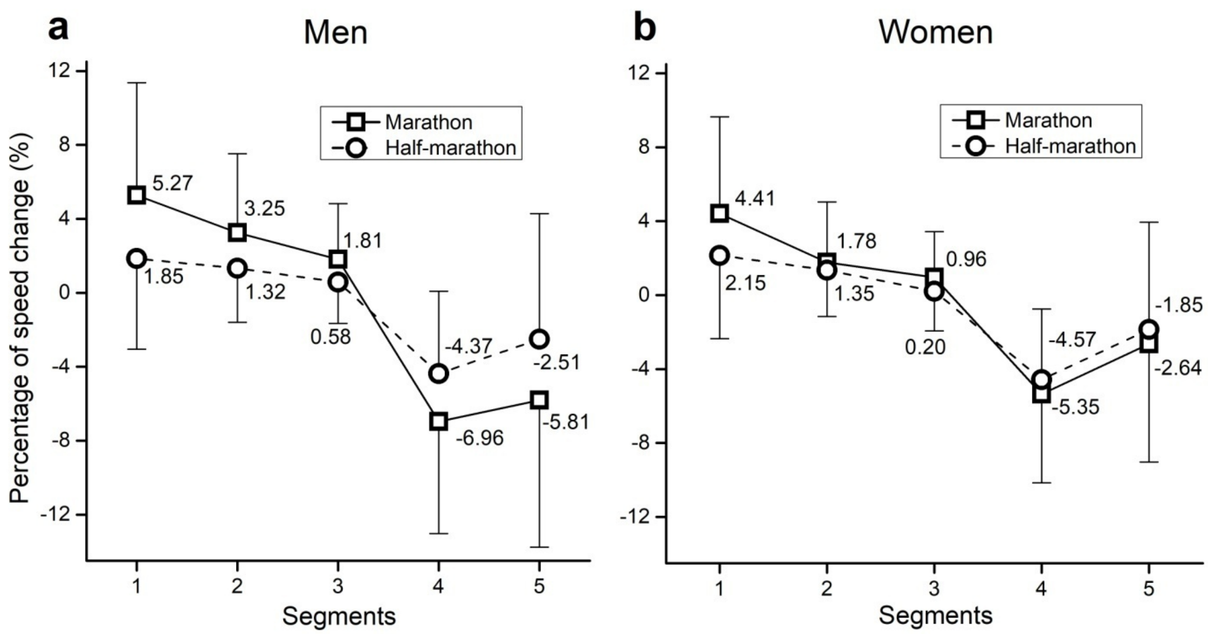
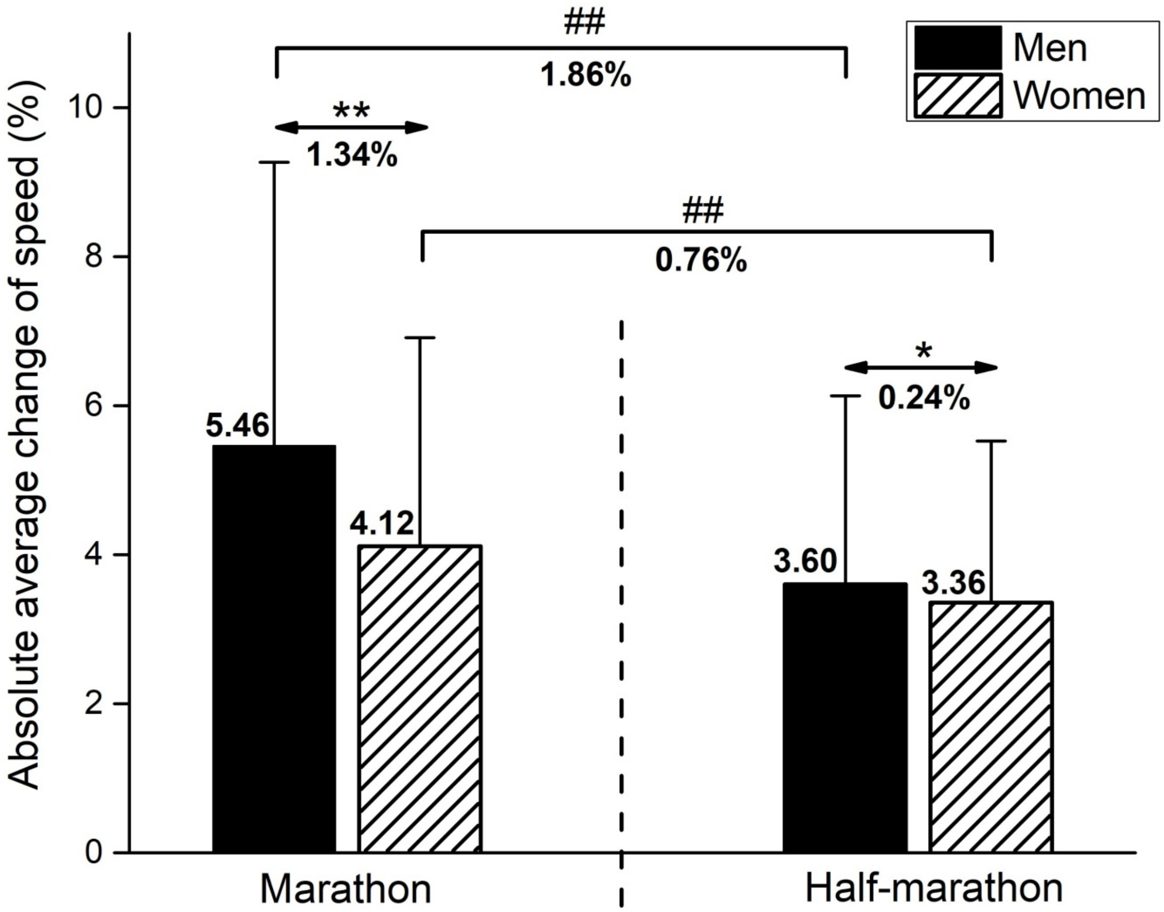

a
Men
b
Women
Marathon
Half-marathon
Percentage of speed change (%)
Segments
5.27
3.25
1.81
1.85
1.32
0.58
-4.37
-2.51
-6.96
-5.81
4.41
1.78
0.96
2.15
1.35
0.20
-4.57
-1.85
-5.35
-2.64

Figure 3



Men
Women
##
1.86%
**
1.34%
##
0.76%
*
0.24%
5.46
4.12
3.60
3.36
Absolute average change of speed (%)
0
2
4
6
8
10
Marathon
Half-marathon